Determining spectral measurements of solar irradiance using an MFRSR-7

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Abstract

Recently the general public has been made aware of environmental issues. The fact that contaminants and air pollution, to name just a few, are affecting our environment has spurred a renewed interest in fighting to maintain our planet clean. What's even more amazing is the fact that scientists are teeming up with students to try to make a difference in today's world. Students are not only learning more about the branch of science but they are also gaining important skills such as teamwork and communication. On the other hand, scientists are benefiting from new ideas and perspectives that students may bring to their field of expertise.

This is one of the many summers that students from all over and from different programs have been sponsored and given the opportunity to do research at various labs across the country. This year at ANL, the environmental research division brought in a new instrument, the MFRSR-7. This machine is capable of measuring global, diffuse and direct components of spectral solar irradiance simultaneously. It may also be used to acquire different types of information, benefiting environmental scientists, climatologists and even meteorologists. It consists of 2 basic components: the detector assembly and the

electronics enclosure. Before running the instrument however, it had to be setup and the software and data logger had to be configured in order to establish communication with the MFR. Basically the instrument alone is not at all complicated to run since the program is set for MS-Windows. Once its setup, the band rotates automatically taking its 4 measurements, assuming it's aligned correctly. The hard part was working with the software. The software came with a QED algebraic data processing language that was tapped via the QED editor. For example, we had to set the site settings, the time intervals, etc. in order to get it running properly.

Along with the MFR, this system came with a data logger to which not only is the MFR hooked up to, but you can also hook up meteorological sensors such as temperature, wind speed and direction and relative humidity. Hooking up the sensors was the most complicated part because it meant editing the language program and certain files in the system.

The system is currently up and running at its first field site, Houston, collecting data. Hopefully the information it will collect may provide us with valuable insight in the areas of environmental and meteorological studies.

Introduction

This is the second summer I have worked for my mentor, Dr. Jeff Gaffney, at ANL. So when he let me choose which project to work on, I decided to go for the one that not only sounded interesting to me but the one that would also challenge me to really think. What can one possibly get by measuring the sun's wavelengths except for a really bad sunburn? The answer: you can determine information about water vapor, aerosols and ozone measurements. Even more, by hooking up meteorological sensors one can gain information about temperature, wind speed and direction and relative humidity, just to name a few.

History

- YESDAS was developed to support and control networks of MFRs
- The MFRSR was designed to perform required spectral measurements of solar irradiance components and to serve as the primary data logging station for a suite of associated meteorological sensors
- The MFR, YESDAS, and associated software were developed for DOE's ARMs program by scientists Lee Harrison, Joe Michalsky, and Jerry Berndt
- In 1993, the Research Foundation of SUNY at Albany and Battelle Memorial Institute jointly granted YES, Inc. an exclusive worldwide license to manufacture and develop MFR systems

Purpose

- MFRSR-7, (Multi-Filter Rotating Shadowband Radiometer), measures global, diffuse and direct normal components of spectral solar irradiance simultaneously
- Detects spectral irradiance at 6 wavelengths, (415, 500, 615, 673, 870, 940nm), and in 1 broadband channel, (300 & 1100nm)
- Broadband channel is an Si detector and the wavelengths detect: 415 & 870nm -> aerosols, 940nm -> water vapor and 500, 615, 673nm -> ozone and aerosols
- All 3 irradiances are measured with the same detector for a given wavelength
- Yesdas is a microprocessor-controlled data acquisition system designed to log data from up to 32 analog sensors and 6 digital sensors

- Yesdas Manager Program is a multi-channel A/D with a memory buffer set for MS-Windows 9x/NT that automates communication, data processing, data display and configuration management for the Yesdas-2 data logger and control system

- QED is an algebraic data processing language that governs Yesdas Manager's data processing

- PCMCIA is a memory card option that extends your Yesdas memory by up to 2MB, offers data preservation and it has an internal backup battery

- The sol file contains the correction factors, processes data from your Yesdas system, provides angular correction tables and describes other daytime instruments that are connected to Yesdas

- The cal file contains the sensitivities for each active Yesdas channel including the head and it also contains formulas necessary to convert data to physical units

Instrumentation

- MFRSR-7 has 2 basic components: 1- detector assembly which includes the sensor head and the stepper and 2- electronics enclosure which includes the microprocessor, data acquisition and the logging circuitry

- A standard system includes the shadow band instrument, yesdas, host software and a PCMCIA card

- YESDAS Manager has 5 basic components: 1- YESDAS Network Management or YESDAS Explorer, 2- terminal emulator, 3- automated attendant, 4- data manager and 5- system profiles

- QED consists of 3 subsystems: 1- automated attendant, 2- web server and 3- data manager

Operation

- The MFR-7 uses an automated rotating shadowband to make measurements
- Global or total horizontal irradiance: first measurement in which the band is rotated to the nadir position
- Diffuse horizontal irradiance: second measurement in which the sun is completely blocked by the band
- Direct normal irradiance component: third measurement which is rotated 9 degrees on either side of the sun, subtracting the first two components yields the direct horizontal irradiance and then dividing this result by the cosine of the solar zenith angle yields the direct normal irradiance component
- The calculated direct solar radiation is thus corrected throughout the day based on the solar position
- The band rotates every 15s; 4 times per min.

- The microprocessor in the yesdas controls the instrument at each measurement interval

- The instrument computes the solar position using an approximation of the solar ephemeris calculation

- For the shadowband to calculate the sun's position, the motor bracket must be aligned to the local geographical north/south meridian, (dependent on the hemisphere)

- The instrument collects and stores data in raw counts where 1 count = 1 mv and in which you may download to your PC for analysis

- The host software can automatically perform the angular corrections

Advantages

- Method permits longer integration time for each measurement because it requires measurements at only 4 shadowband positions rather than a continuous scan across the sky
- The excess sky blockage correction improves measurement accuracy
- 3 irradiance components are derived from a single optical detector
- Temperature controlled, desiccated enclosure ensures the elimination of ambient T-induced errors in solar radiation data
- MFRSR uses a computed ephemeris to position the band for the blocking measurements and doesn't depend on detection of a minimum irradiance
- Simpler, less expensive and more robust

Disadvantages

- Instrument must be properly aligned
- Since the direct beam irradiance is derived by the difference, it's the most sensitive to experimental error

Data Analysis

- Some scientists measure the direct and global irradiance measurements
- Others use these measurements to derive the total column aerosol optical depth, ozone and water vapor measurements
- You interpret the graphs exactly as its shown: total, direct and diffuse irradiance measurements in W/(m^2)
- Yesdas Manager can also produce a Langley Analysis report if desired
- Scientists can also get information on climate and weather by hooking up meteorological sensors to the data logger

Conclusion

Working on this project for the past two months has not been an easy task. Not only did I learn to set up, run and work with this instrument but I also learned the importance of communication and networking skills. But I am so grateful to have had the opportunity to learn to fend for myself, to be able to do the research work and apply it and to not be afraid to ask for help when the need arose.

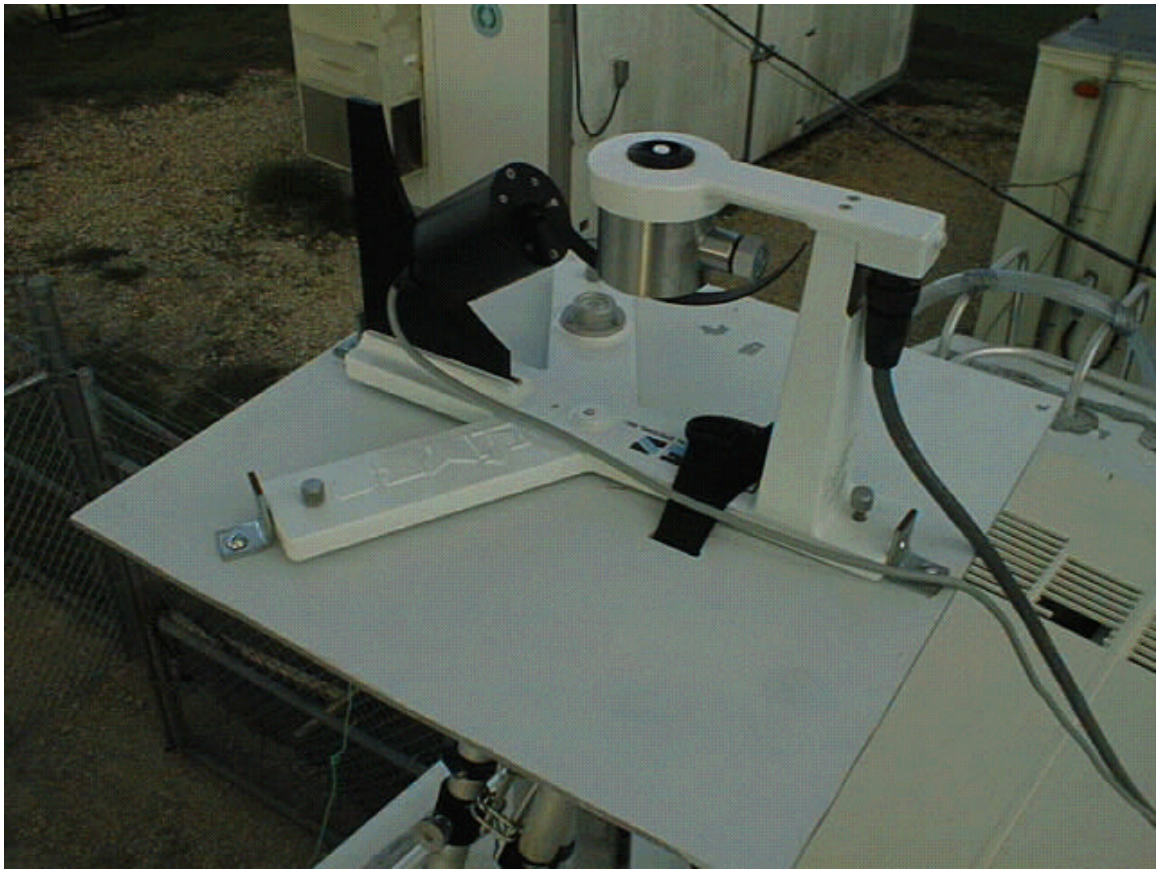
This instrument is only roughly 8 years old in the making and just think of all the valuable information that it will be able to gather and tell us about atmospheric chemistry and meteorological studies in the near future. The Yesdas-2 system alone can be

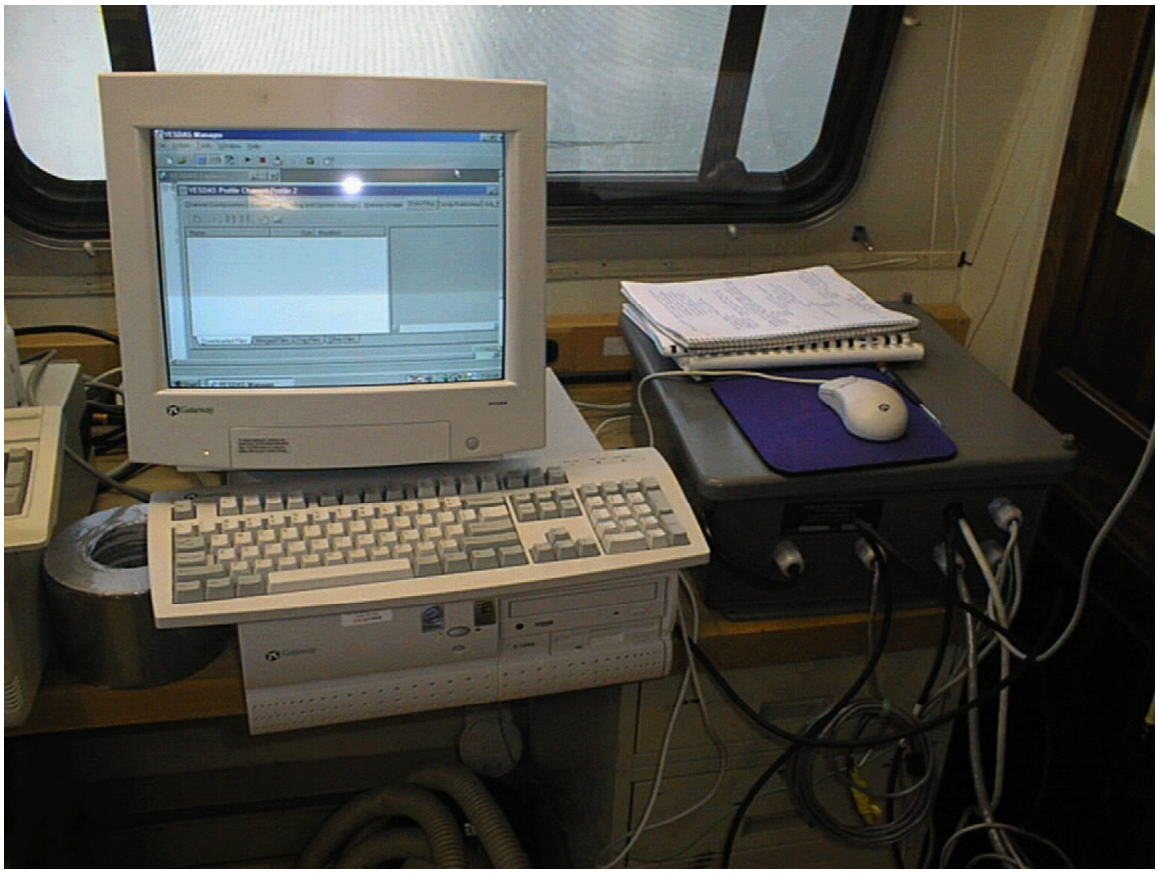
applied in meteorological data, acquisition industrial monitoring, EPA compliance and general research. Meteorologists, climatologists and environmental scientists may all benefit from MFR systems.

Acknowledgements

There are a few people whom I owe my respect and sincere thanks to who without them, I wouldn't have been given this wonderful opportunity to gain some experience and knowledge this summer here at ANL through the GCEP Program. These people are: Dr. J. Gaffney, Dr. N. Marley, Dr. Paul Drayton, Dr. P. Doskey, Mr. T. Martin, Mary Kinney, Milt Constantin, Dr. Sadik and of course the GCEP Students.

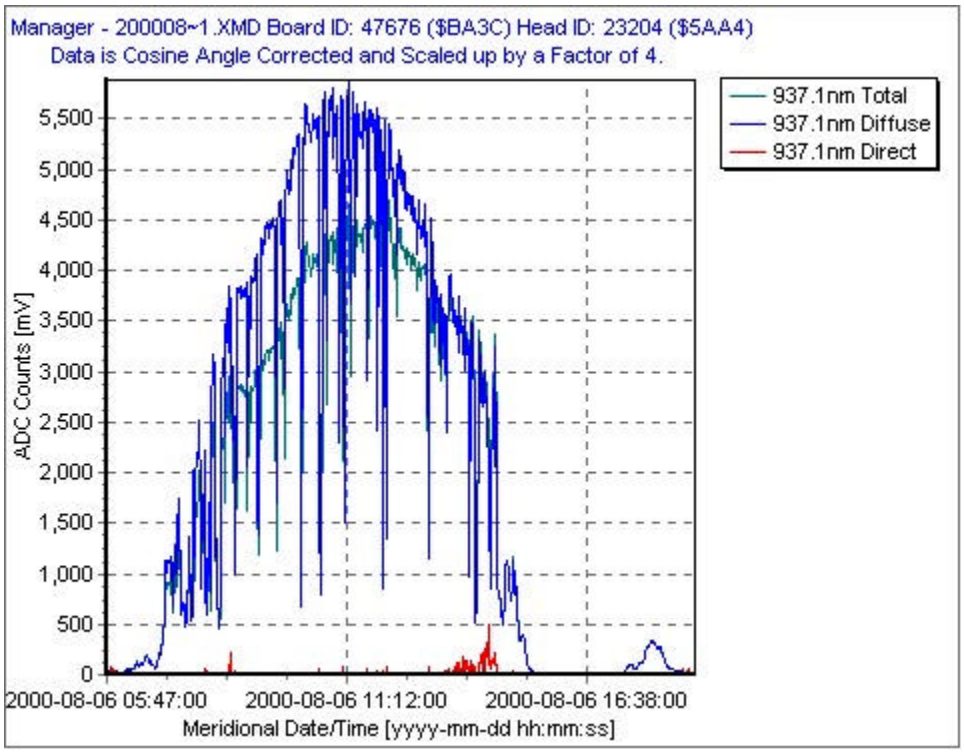
MFRSR-7

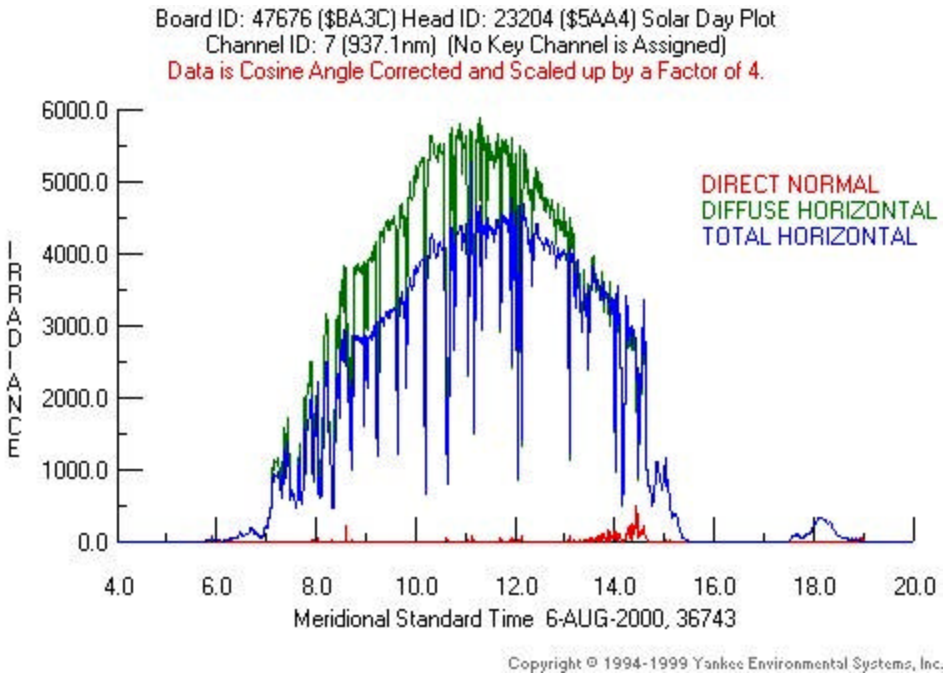




Yesdas datalogger and computer system

Results from the Houston Site aug.-sept. 2000

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4000.0
3000.0
2000.0
1000.0
0.0
DIRECT NORMAL
DIFFUSE HORIZONTAL
TOTAL HORIZONTAL
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6.0
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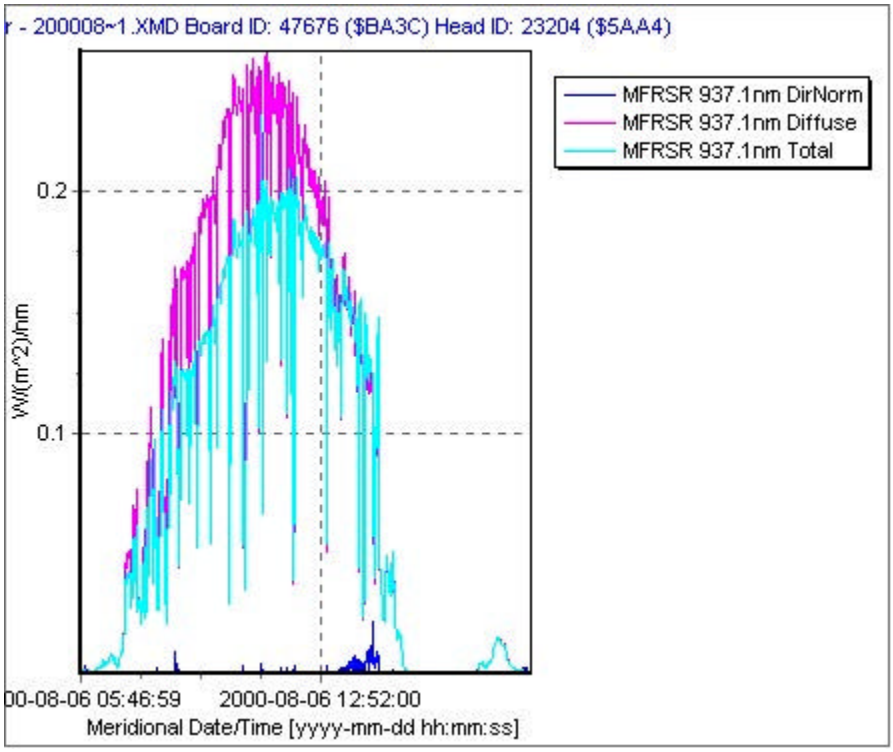
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